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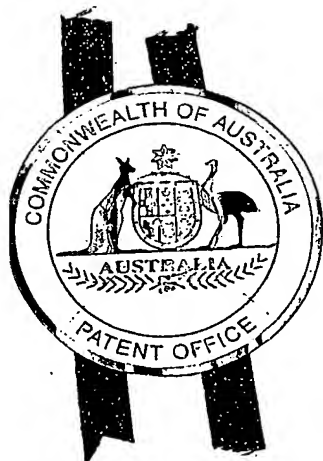
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I, JONNE YABSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PS 0765 for a patent by CERAMIC FUEL CELLS LIMITED as filed on 26 February 2002.

WITNESS my hand this
Thirtieth day of April 2003

JR Yabsley

JONNE YABSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

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PROVISIONAL SPECIFICATION

for the invention entitled:

"A Fuel Cell Gas Separator Plate"

The invention is described in the following statement:

A FUEL CELL GAS SEPARATOR PLATE

The present invention relates to fuel cells and is particularly concerned with gas separators between adjacent fuel cells.

5

The purpose of a gas separator in planar fuel cell assemblies is to keep the oxygen containing gas supplied to the cathode side of one fuel cell separate from the fuel gas supplied to the anode side of an adjacent fuel cell, and to conduct heat generated in the fuel cells away from the fuel cells. The gas separator may also conduct electricity generated in

10   the fuel cells away from the fuel cells. Although it has been proposed that this function may alternatively be performed by a separate member between each fuel cell and the gas separator, much development work has been carried out on electrically conductive gas separators.

15   Sophisticated ceramics for use in fuel cell gas separators have been developed which are electrically conductive, but these suffer from a relatively high fragility, low thermal conductivity and high cost. Special metallic alloys have also been developed, but it has proved difficult to avoid the various materials of the fuel cell assembly and the interfaces between them degrading or changing substantially through the life of the fuel cell,

20   particularly insofar as their electrical conductivity is concerned, because of the tendency of different materials to chemically interact at the high temperatures which are required for efficient operation of a solid oxide fuel cell. For example, most metallic gas separators contain substantial quantities of the element chromium which is used to impart oxidation resistance to the metal as well as other properties.

25

It has been found that where chromium is present in more than minute quantities it may combine with oxygen or oxygen plus moisture to form highly volatile oxide or oxyhydroxide gases under conditions which are typical of those experienced in operating solid oxide fuel cells. These volatile gases are attracted to the cathode-electrolyte interface

30   where they may react to form compounds which are deleterious to the efficiency of the fuel cell. If these chromium reactions are not eliminated or substantially inhibited, the

performance of the fuel cell deteriorates with time to the point where the fuel cell is no longer effective.

Several of these metallic alloys and one proposal for alleviating this problem are described
5   in our patent application WO96/28855, in which a chromium-containing gas separator is provided with an oxide surface layer which reacts with the chromium to form a spinel layer between the substrate and the oxide surface layer and thereby tie in the chromium. However, these specialist alloys remain expensive for substantial use in fuel cell assemblies and it would be preferable to have a lower cost alternative.

10

Special stainless steels have also been developed which are stable at high temperature in the atmospheres concerned, but they generally contain substantial amounts of chromium to provide the desired oxidation resistance and special coatings or treatments are required to prevent the chromium-based gases escaping from a gas separator formed of these steels.
15   Another approach to a heat resistant steel gas separator is described in our patent application WO 99/25890. However, once again, all of these heat resistant steels are specialist materials whose cost will remain high unless substantial amounts can be produced. Furthermore, the thermal and electrical conductivity of heat resistant steels is low relative to many other metals and alloys, for example, 22 - 24 W/m.K compared to 40-
20   50 W/m.K for the Siemens-Plansee alloy described in WO96/28855. To compensate for this, the thickness of the steel gas separator has to be increased, increasing the mass and cost of a fuel cell stack.

In yet another proposal, disclosed in our patent application WO 00/76015, we have found
25   that copper-based gas separators may be successfully utilised in solid oxide fuel cell assemblies without poisoning the anode. Such a gas separator member comprises a layer of copper or copper-based alloy having a layer of oxidation-resistant material on the cathode side.

30   One of the major difficulties with developing a satisfactory gas separator plate is ensuring that its coefficient of thermal expansion ("CTE") is at least substantially matched to that of

- 3 -

the other components of the fuel cell assembly. For example, solid oxide fuel cells comprising an oxide electrolyte with a cathode and an anode on opposed surfaces, operate at temperatures in excess of 700°C, and the alternating gas separator plates and fuel cells are generally bonded or otherwise sealed to each other. Thus, any substantial mismatch in

5   the CTE between the two components can lead to cracking of one or both of them, with resultant leakage of the fuel gas and oxygen-containing gas across the component or components, and eventually to failure of the fuel cell stack.

A particular difficulty with developing a suitable fuel cell gas separator is providing a

10   material that provides all four functions of separating the fuel gas on one side from the oxygen-containing gas on the other side, being thermally conductive, having a CTE substantially matched to that of the other fuel cell components, and being electrically conductive.

15   In order to meet these requirements, it has been proposed to provide a gas separator plate formed principally of a material which may not be electrically conductive but which meets the other requirements, and to provide electrically conductive feedthroughs through the thickness of the plate. One such proposal is made in EP 0993059. In this specifcation, a ceramic gas separator plate, preferably stabilized zirconia, has passages therethrough

20   which are filed with cathode material from the cathode side and with anode material from the anode side, or with a single material composition such as doped chromite, silver-palladium or Plansee alloy. Another such proposal is made in Kendall *et al.* in *Solid Oxide Fuel Cells IV*, 1995, pp.229-235, in which the plate is formed of a zirconia material and lanthanum chromite rivets extend through holes in the plate.

25

Thus, the feedthrough material is different to that of the principal separator plate material. However, this can lead to the disadvantage of the feedthrough material becoming loose in the plate material as the gas separator plate is subjected to thermal cycling, due to the different CTEs, and permitting leakage of gas through the passages in which the

30   feedthroughs are formed.

An aim of the present invention is to provide a fuel cell gas separator which alleviates the above mentioned disadvantages.

5   According to a first aspect of the present invention there is provided a fuel cell gas separator plate comprising a first layer which is formed of a material that is impermeable to gases, a second layer which is formed of a material that is impermeable to gases, the first and second layers have perforations through their thickness which are closed by electrically conductive plug material, and a third intermediate layer between the first and

10   second layers which is electrically conductive and is in electrical contact with the plug material in the passages through the first and second layers.

By the present invention, the advantage of separating the electrical conductivity of the gas separator plate from the plate material is achieved, and the risk of leakage of gases through

15   the perforations should the plug material become loose is alleviated by providing the intermediate layer between the first and second layers.

The materials of the first and second layers of the gas separator plate are preferably the same, in order to minimise differences in the CTE of the two layers, but this is not

20   essential. The material or materials are preferably selected with a CTE that substantially matches that of the fuel cell, but any suitable material may be selected, including electrically conductive materials. In a solid oxide fuel cell assembly, in which the electrolyte material is preferably a zirconia and may be the principal layer that supports the electrode layers, the material of the first and second layers of the gas separator plate is

25   advantageously zirconia. The zirconia of the first and second layers may be yttria-stabilised, for example 3 to 10% Y. Alternatively, the zirconia may include other materials while retaining a zirconia-based structure. For example, the zirconia may be a zirconia alumina having up to 15 wt%, or even up to about 20 wt%, alumina. For convenience, all such materials are hereinafter referred to as zirconia.

30

The thickness of each of the first and second layers of the gas separator plate is preferably

in the range 20 to 250 μm. While a smaller thickness could be used, the layer becomes difficult to manufacture and it becomes more difficult to ensure that the layer is dense, that is that it is gas tight to the gases in the fuel cell assembly. Greater thicknesses may be used but are unnecessary, and more preferably the thickness is less than 150 μm in order to

5   minimise the mass and height of the gas separator plate and therefore of a stack of fuel cell assemblies including the gas separator plate. Most preferably the thickness of each of the first and second layers is in the range of 50 to 100 μm.

The first and second layers may be formed by any suitable means, depending particularly

10 upon their material. A zirconia first or second layer, for example, may be formed by tape casting the green material and sintering. Suitable manufacturing methods may be readily identified and do not form part of the present invention.

For convenience, the perforations preferably extend perpendicularly through the layers. In

15 a preferred embodiment, the perforations in the first layer are offset relative to those in the second layer so that any gas that is able to leak through one or more perforations in one of the first and second layers must pass along or across the third intermediate layer and leak through one or more perforations in the other of the first and second layers in order to leak through the full thickness of the gas separator plate.

20

The perforations through the first and second layers preferably have a diameter or average cross-sectional dimension in the range of 50 to 1000 μm. The perforations may be formed during manufacture or subsequently, for example by laser cutting. The minimum size of the perforations is a function of the difficulty of forming and filling them with the

25 electrically conductive plug material. More preferably, the average cross-sectional dimension is in the range 200 to 400 μm, for example about 300 μm.

The minimum number of perforations is a function of their size, the electrical conductivity of the plug material and the electrical current to be passed through the gas separator plate.

30 If the perforations have an average cross-sectional dimension towards the upper end of the preferred range, they may be fewer in number and more widely spaced. This may be

advantageous in alleviating the risk of leakage through the aforementioned preferred embodiment of the gas separator plate, since the gas may have further to travel between the perforations in the first and second layers, along or across the third intermediate layer. Preferably, the total area of perforations through each of the first and second layers is in the range of 0.1 mm^2 to 20 mm^2 per 1000 mm^2 surface area (on one side only) of the layer, more preferably in the range 0.2 mm^2 to 5 mm^2 per 1000 mm^2. In our currently preferred embodiment, there are 4 perforations having an average diameter of about 300 μm per 1000 mm^2 through each of the first and second layers. All of these are sealed with plug material to prevent fuel cell gases passing through the layer.

Advantageously, the electrically conductive plug material in the perforations of each of the first and second layers is the same, and, more conveniently, is the same as the electrically conductive material of the third intermediate layer, but this is not essential. Any suitable conducting material may be utilized including conducting metals, oxides and ceramics. One possible conducting oxide is cobaltite. However, conducting metals are preferred, particularly, for example, Ag, Au, Pt, Ni, and alloys containing one or more of these. The preferred material of the third intermediate layer and the preferred plug material is silver. The silver may be commercially pure or an alloy. Alternatively, the plug material may be a silver composite, such as a composite of silver in glass.

Advantageously, the plug material and third intermediate layer provide a thermally conductive path for transmission of heat away from the fuel cells on opposite sides.

The plug material may be introduced to the perforations by any suitable means. For example, a coating of the plug material may be applied to one or both surfaces of each of the first and second layers, with the plug material being permitted to flow into the perforations. Alternatively, the material could be injected into the perforations. More preferably, the plug material is introduced to the perforations in the manner described below with reference to the second aspect of the invention.

Preferably, the third intermediate layer has a thickness in the range 10 to 500 μm, but

advantageously the thickness is towards the lower end of the range in order to minimise the mass and height of the gas separator plate. More preferably, therefore, the thickness of the third intermediate layer is in the range 10 to 100 μm, most preferably less than 60 μm. The preferred materials for the third intermediate layer are as described above for the plug

5   material.

The total thickness of the planar first, second and third layers (i.e. excluding any surface formations on the first and second layers) is preferably no more than 500 μm. Most preferably the thickness is substantially less than this in order to minimize the overall

10   height and mass of a full cell stack utilizing the gas separator plates, for example no more than 200 μm.

The third intermediate layer may be formed by any suitable means, for example by sputtering, screen printing, tape casting or otherwise coating onto one of the first and

15   second layers, after which the other of the first and second layers is superposed onto the third intermediate layer. Alternatively, third intermediate layer material may be coated on to both of the first and second layers, with the first and second layers then being superposed to form the intermediate layer. Either of these coating procedures may be used to also plug the passages in one or both of the first and second layers, if the material of the

20   intermediate layer is the same as the plug material. Preferably, the third intermediate layer is initially laid with a relatively greater thickness than the final thickness and is subsequently compressed between the first and second layers to densify the third intermediate layer such that it will not permit the transmission of the gases in the fuel cell assembly. Such pressure may be used to force the material of the third intermediate layer

25   into the perforations of the first and second layers.

Thus, according to a second aspect of the present invention there is provided a method of forming a fuel cell gas separator plate which comprises:

        providing first and second layers of the plate, said first and second layers being
30   formed of material that is impermeable to gases and having perforations through their thickness;

superposing the first and second layers with a third layer of electrically conductive material having a first thickness interposed between the first and second layers;

compressing the superposed first, second and third layers under conditions which cause the electrically conductive material to flow to produce a gas separator plate in which

5   the third layer of electrically conductive material has a second thickness less than the first thickness and said electrically conductive material has flowed into the passages in the first and second layers to plug said perforations.

The method of the second aspect of the invention may be performed at a temperature at

10   which the electrically conductive material flows at the pressure used in the method. In a preferred embodiment using commercially pure silver as the electrically conductive material, the method may be performed at or near room temperature.

Preferably, the method of the second aspect of the invention includes forming or orienting

15   the first and second layers such that the perforations through said layers are not coincident.

In order to ensure that the fuel cell gas separator plate does transmit electricity from the fuel cell on one side to the fuel cell on the other side, the plug material in the perforations may extend to the exposed face of the respective one of the first and second layers.

20   Alternatively, the plug material may have an electrically conductive coating on it which extends to the exposed surface and which may protect the plug material and/or the interface between the gas separator plate and the adjacent electrode. Such a coating will depend upon the plug material and may also depend upon to which electrode the respective first or second layer is exposed. For example, for a silver plug material, a Ni or Pt

25   protective coating may be provided at the anode side and a Ag-Sn protective coating at the cathode side to alleviate loss of the plug material through evaporation or "wicking" to other nearby components.

To enhance electrical current flow between the adjacent fuel cell and gas separator plate,

30   the aforementioned protective coating may extend across the exposed face of the separator plate, for example with a thickness in the range of 10 to 150 μm. Alternatively, a

respective mesh or other current collector may be interposed between the gas separator plate and the electrodes of the adjacent fuel cells. The mesh or other current collector may define, or partly define, gas passages through which the air or other oxygen-containing gas on the cathode side of the gas separator plate and the fuel gas on the anode side of the gas

5   separator plate is passed over the adjacent fuel cell electrode.

Alternatively, or in addition, to the aforementioned gas flow passages defined or partly defined by a current collector, surface formations may be provided on the exposed faces of the gas separator to define gas flow passages. The surface formations may be in the form

10   of parallel ridges which may be integrally formed in the material of the first and second layers, or may be affixed to the surface of the first and second layers. Unless the surface formations are electrically conductive, the perforations should extend through the surface formations, and the plug material, or additional electrically conductive material in the perforations, should extend to the outer surface of the ridges. The surface formations may

15   have any suitable height to provide for the necessary gas flow, for example up to about 750 μm, preferably about 500 μm high.

Advantageously, the plug material-filled perforations are covered by an array of parallel ridges on both sides, which extend parallel to the desired direction of the gas flow. The

20   ridges on opposed sides of the gas separator plate may extend parallel to each other or perpendicularly to each other, depending upon whether the fuel gas and oxygen-containing gas are to be in co- or counter-flow, or in transverse – or cross - flow. The ridges may be formed of any suitable material that is electrically conductive and structurally and chemically stable. In one embodiment, the ridges on each side of the gas separator plate

25   are made of the same material as the respective electrode that they contact. Thus, on the cathode side the ridges may be formed of a conductive Perovskite such as lanthanum strontium manganate, preferably coated with a metallic silver coating up to about 100 μm, preferably about 50 μm, thick. On the anode side, the ridges may be formed of a nickel-zirconia cermet, preferably with a metallic nickel coating up to about 100 μm, preferably

30   about 50 μm, thick.

One embodiment of a fuel cell gas separator plate in accordance with the invention will now be described by word of example only with reference to the accompanying drawings in which:

5   Figure 1 is a schematic exploded side view of a fuel cell stack incorporating one embodiment of a gas separator plate in accordance with the invention;

Figure 2 is a schematic side view of one of the fuel cell gas separator plates of Figure 1 during its manufacturing process;

Figure 3 is a plan view of a fuel cell stack incorporating another embodiment of gas

10   separator plates in accordance with the invention;

Figure 4 is an exploded schematic perspective view looking downwards and illustrating the general orientation of cell plates and gas separator plates within the stack shown in Figure 3;

Figure 5 is a schematic perspective view looking upwards at the cell plates and gas

15   separator plates in the same exploded positions shown in Figure 4;

Figure 6 is a perspective view of the topside of one of the cell plates shown in Figure 4;

Figure 7 is a cut-away perspective view of the topside of one of the gas separator plates shown in Figure 4;

Figure 8 is a cut-away underside view of the gas separator plate shown in Figure 7; and

20   Figure 9 is a diagrammatic cross-sectional view through a portion of a gas sealed assembly between the plates shown in Figures 3 and 4.

Referring to Figure 1 there is shown an array 10 of alternating fuel cells 12 and gas separator plates 14 in accordance with the invention. The fuel cells 12 are planar and

25   comprise a solid oxide electrolyte support layer 16 with an anode layer 18 on one side and a cathode layer 20 on the other side. The electrolyte is preferably a yttria-stabilized zirconia such as 3Y, 8Y or 10Y. The anode is preferably a nickel-zirconia cermet and the cathode is preferably a conductive Perovskite such as lanthanum strontium manganate. Such solid oxide fuel cells are well known and will not be described further.

30

Each gas separator plate 14 has a three-layer sandwich structure with first and second outer

layers 22 and 24, and a third intermediate layer 26.

The first and second layers are conveniently formed of a zirconia to substantially match the CTE of the electrolyte support layer 16 of the fuel cells 12. The zirconia may be yttria-

5 stabilized, but could be, for example, an alumina-added zirconia with up to 20 wt.% alumina.

The zirconia is not electronically conductive, and each of the first and second layers 22 and 24 has a plurality of perforations 28 extending perpendicularly through its thickness which

10 are filled with an electrically conductive plug material. The plug material is conveniently a silver-based material such as commercially pure silver, a silver alloy or a composite of silver in glass.

The perforations 28 in the first and second layers in each gas separator plate 14 are offset

15 so that no perforation in the first layer is coincident with a perforation in the second layer. The material of the third intermediate layer 26 is the same as the plug material in the first and second layers, and has a thickness of less than 60 μm.

The perforations have an average cross-sectional dimension of about 300 μm, and the plug

20 material 30 seals the perforation to present a total cross-sectional area of plug material in the range of 0.2 to 5 mm^2 per 1000 mm^2 of surface area on one side only of each of the first and second layers.

Figure 2 illustrates one method of forming the gas separator plate 14. In this method, a

25 thicker layer of the material of the third intermediate layer, for example about 200 μm, is screen printed onto the inner surface of the second layer 24. As shown in Figure 2, some of the coated material enters the perforations 28 in the second layer during the coating process. The first layer 22 is then superposed onto the coated material of the third layer on the second layer, with the perforations 28 in the first layer offset relative to the perforations

30 28 in the second layer. For a third intermediate layer material comprising a composite of silver in glass, the screen printing may be performed at or near room temperature.

Sufficient pressure is then applied through the first layer 22, as represented by the downwards arrows in Figure 2, and the assembly heated to a temperature at which the particular glass contained in the composite softens and can flow under the pressure. This reduces the material of the third layer to the desired thickness and forces the composite

5   material further into the perforations 28 of the second layer 24 as well as into the perforations 28 in the first layer 22 to act as the electrically conductive plugs. At the operating temperature of the fuel cell, the glass in the composite is a viscous fluid and forms a gas barrier, while the silver provides electrical conductivity. At low temperatures, or at shutdown, the glass in the composite returns to a glass state. Should the composite

10   material become damaged in this condition, once it returns to operating temperature the glass returns to a fluid state and will recover its sealing properties.

The outer surfaces of the gas separator plate 14 may then be coated with conductive materials such as an Ag-Sn alloy on the cathode side and nickel metal on the anode side.

15   This plating may act to fill the perforations 28 from the outside and ensure that electrically conductive paths are provided via the perforations and the third intermediate layer from one of the outer surfaces to the other outer surface of the gas separator plate 14, as represented by the upwards arrows in Figure 1.

20   Referring to Figure 1 again, one current collector 32 is illustrated schematically between the upper pair of fuel cell 12 and gas separator plate 14, and this may define gas flow passages between the two structures. Such gas flow passages are necessary between each pair of adjacent gas separator plates and fuel cells, but are omitted for convenience. They are conveniently in the form of ridges on the outer surfaces of the gas separator plates 14,

25   as illustrated in and described with reference to Figures 3 to 9.

Referring to Figures 3, 4 and 5 a solid oxide fuel cell stack assembly 102 comprises a stack 103 of alternating fuel cell components, in the form of cell plates 110 and gas separator plates 130 held within a tubular housing 104. All of the cell plates 110 are identical and all

30   of the separator plates 130 are identical. Typically there might be 20 to 500 of each of these plates in the stack 103. Fuel gas and air are supplied at one axial end of the stack

assembly and exhaust gases are collected at the other end. Either end is suitable for the supply and exhaust functions and the manifold flows may be co-current or counter-current. In the described embodiment, the fuel and air supplies are both at the bottom and exhausts are at the top, so the flows are co-current, but in many circumstances it is preferred for the

5   fuel to be supplied from the bottom and the air to be supplied from the top in a countercurrent arrangement.

Referring to Figures 3 to 8, the cell plates 110 and separator plates 130 have the same outer shape, which could be described as generally trilobular, or part way between a circle and a

10   triangle. The shape could alternatively be described as generally circular with three rounded lobes extending therefrom. Two of the lobes 174 and 176 are the same size and the third lobe 172 extends about 50% further than the others circumferentially around the periphery of the plate. At each lobe 172, 174 and 176 a kidney shaped aperture (numbered 114, 116 and 118 in the cell plate and 115, 117 and 119 in the separator plate respectively)

15   extends through the plate. The larger lobes 172 carry the larger apertures 114 and 115. A system of ridge shaped seals on the faces of the plates directs the gas flows within the stack. These seals are described hereinafter in more detail.

In operation of the stack, fuel gas flows up through inlet port 114 in the cell plate 110 and

20   (at arrow A) across the face of the fuel cell anode, then divides its flow (arrows B and C) to exit up through exhaust ports 117 and 119 respectively. On the opposite face of the cell plate, air which has passed up the side of the stack 103 through the inlet manifold between the stack and the housing flows in (arrow D) from the periphery of the stack 103 then across the face of the fuel cell cathode before dividing its flow to exit (arrows E and F)

25   from the periphery of the stack 103 and then continuing up through the exhaust manifolds to the top of the stack.

Fuel distribution and exhaust collection manifolds 105 and 106 respectively, are formed by interlocking components of the plates 110 and 130 which conduct the fuel inlet and

30   exhaust streams past the air side of the plates. Air supply and collection manifolds 107 and 108 respectively are created by the volumes formed between the outside of the stack 103

and the inside wall of the housing 104. Fibrous seals 109 between the stack 103 and the inside wall of the housing 104 separate the air supply manifold 107 from the two air collection manifolds 108.

5   The housing 104 is constructed of a suitable heat resistant steel sheet material, which may be lined with a suitable insulating material, and is slid into position over the stack 103 after the plates 110 and 130 have been assembled together.

Referring to Figure 4, the generally planar cell plate 110 is intended for use in the stack
10   assembly 102. The square fuel cell 112 on the plate has an electrolyte supported structure with the electrolyte material extending out to form the main body of the plate 110. The electrolyte is preferably a yttria-stabilized zirconia and suitable 3Y, 8Y and 10Y materials are known to those in the art. The anode is preferably a nickel-zirconia cermet and the cathode a lanthanum strontium manganate.

15
A pair of parallel ribs 120 and 121 project from the planar surface 124 of the cell plate 110 forming a valley or groove 122 therebetween. The surface 124 is the upper surface of the cell plate when the stack is oriented for use. Each rib 120 and 121 forms a contiguous path around the perimeter of the region which the fuel gas is permitted to contact. In all the
20   Figures, the thickness of the plates 110 and 130 and the height of the ribs is shown greatly exaggerated in order to more clearly explain the invention. In this embodiment the fuel cell 112 is 2500mm^2, the cell plate is 150µm thick and the ribs are approximately 500µm high, 1mm wide and approximately 2mm apart.

25   Referring to Figure 5, a generally planar gas separator plate 130 is shown which is intended to mate face to face with the cell plate 110. The surface 133 is the upper surface of the separator plate 130 when the stack is oriented for use. Pairs of parallel ribs 136 and 137 project from the planar surface 133 of the separator plate 130 forming valleys or grooves 138 therebetween. A single rib 142 on the underside of plate 130 engages along
30   the full length of valley 122 and, by use of glass sealant material in the valley, a gas-tight

seal is produced. In operation of the stack, air flows from a peripheral port 142 across the face 133 to exit through peripheral ports 144 and 146.

5   The separator plate 130 is manufactured principally from a zirconia, preferably the same material as that used for the body of the cell plates. This greatly minimizes thermal stresses in the assembly during start-up, operation and shut-down. Alternatively a different zirconia of substantially the same thermal expansion characteristics may be used. A suitable material is an alumina-added zirconia with up to 20 wt.% alumina. However, the overall structure of the separator plate 130 is as described with reference to Figures 1 and

10   2, that is a sandwich structure with an intermediate electrically conductive layer between opposed outer layers.

The separator plate 130 has an array of perforations 150 of about 300 μm diameter passing through the thickness of the outer layers. These occupy a region in the plate 130 which is

15   directly opposite the region occupied by the fuel cells 112 in plates 110, but the perforations in the two outer layers are offset from each other. The perforations 150 are filled with metallic silver in the manner described with reference to Figures 1 and 2. Alternatively the perforations may be filled with a silver composite, such as a composite of silver in glass. In any event, the electrically conductive silver based plug which fills each

20   perforation is preferably plated with a protective Ni or Pt coating on the anode side 132 and an Ag-Sn coating at the cathode side 133.

An array of parallel ridges 148 are positioned parallel to the air flow stream on the cathode side 133. These ridges 148 are each aligned over a corresponding row of perforations 150.

25   To assist explanation, about half of the ridges 148 have been removed in Figures 4 to 8. The ridges 148 perform three major functions. First, they provide an electrically conductive path between the electrically conductive plug material in holes 150 and the fuel cell 112. Second, they direct air flow over the cathode, and, third, they provide physical support to brace the thin and fragile plates. The ridges 148 thus need to be both

30   electrically conductive and structurally and chemically stable. The ridges 148 could be

made from the same material as the cathode it contacts. They could be made from a conductive perovskite with a metallic silver coating about 50μm thick.

5   Referring to Figure 8, the anode side 132 shown of the gas separator plate 130 is that which is also visible, but partly obscured, in Figure 5. Anode side 132 is intended to mate face to face with the anode face of a cell plate 110. The surface 132 is the underside of the separator plate 130 when the stack is oriented for use.

A rib 134 projects from the planar surface 132 of the separator plate 130 and forms a
10   contiguous path around the perimeter of the region which the fuel gas is permitted to contact. Surfaces 124 and 132 face each other when the stack is assembled and rib 134 nests between ribs 120 and 121.

On the underside of plate 130, (ie. surface 132 shown in Figure 8) the rows of Ag-filled
15   perforations 150 are covered by an array of parallel ridges 162 which, like ridges 148 on the opposite face 133, are positioned parallel to the fuel gas flow stream. Again, about half the ridges 148 are cut away from Figure 4 to 8 to assist visualization of the structure. The ridges 148 perform as a current collector whereby current is conducted between the electrically conductive plug material in the perforations 150 and the anode. They also
20   provide physical support for the plates and additionally provide means for directing and distributing gas flow in the narrow spaces between the cell plates and separator plates. The ridges 148 are approximately 500 μm high and could be formed from the same material as the anode with an overlay (approx. 50 μm thick) of nickel.

25   Referring to Figure 9, a pool of glass sealant 140 is located between the ribs 120 and 121 along the full length of groove 122 and is pressed into by rib 134. During manufacture, the glass is introduced as a powder and the stack assembled before the stack is heated to melt the glass in order to form the required seal. In operation of the stack the glass sealant 140 is fully molten but highly viscous.

30

In one embodiment the peak 151 of the rib 134 contacts the floor 156 of the valley 122 leaving at least one of the flanks 152 of the rib 134 clear of the flanks 158 of the valley 122 and leaving the peaks 160 and 161 of ribs 120 and 121 clear of the basal surface 154. In this case the glass sealant 140 would be retained by surface tension between the spaced

5   flanks 152 and 158.

In a second, and preferred, embodiment the peaks 160 and 161 contact the basal surface 154 leaving at least one of the flanks 152 clear of the flanks 158 and the peak 150 clear of the floor 156. In this case the sealant 140 would be retained between the peak 150 and the

10   floor 156, with some displaced outwardly to between the spaced flanks 152 and 158.

In a third embodiment both flanks 152 would engage corresponding flanks 158 leaving the peaks 160 and 161 clear of the basal surface 154 and the peak 150 clear of the floor 156. In this case the sealant 140 would fill the volume between the peak 150 and the floor 156.

15

Provision of fuel manifolds internally of the plates and air manifolds externally of the plates optimizes the structure of the cell plates from both an economic and power producing perspective. For example, known stack constructions employ either fully internalized manifolds, i.e. arranged within the cell plate structure, or fully externalized

20   manifolds. If the manifolds are fully internalized then the construction of the cell plates is more complex and a significant portion of the plates needs to be dedicated to formation of the respective manifolds, i.e. each plate has an increased aperture area whereas the actual surface area of the plates of the stack 103 is comparatively larger to maximize generation of electric current produced by the stack. Internalizing the fuel manifold also means the

25   overall structure is fairly robust since external connections which may otherwise be subject to fatigue or leakage are minimized.

Whilst the above description includes the preferred embodiments of the invention, it is to be understood that many variations, alterations, modifications and/or additions may be

30   introduced into the constructions and arrangements of parts previously described without departing from the essential features or the spirit or ambit of the invention.

It will be also understood that where the word "comprise", and variations such as "comprises" and "comprising", are used in this specification, unless the context requires otherwise such use is intended to imply the inclusion of a stated feature or features but is not to be taken as excluding the presence of other feature or features.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgment or any form of suggestion that such prior art forms part of the common general knowledge in Australia.
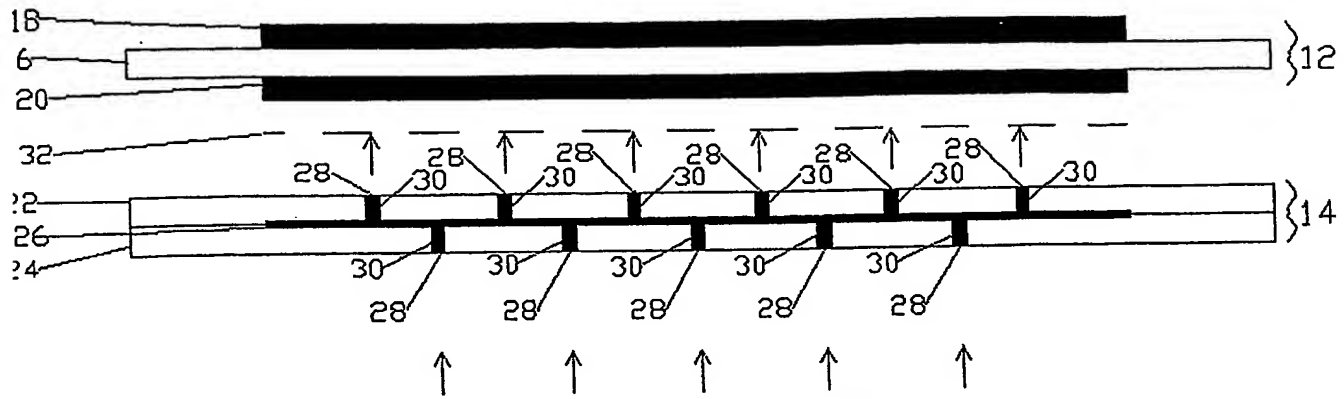
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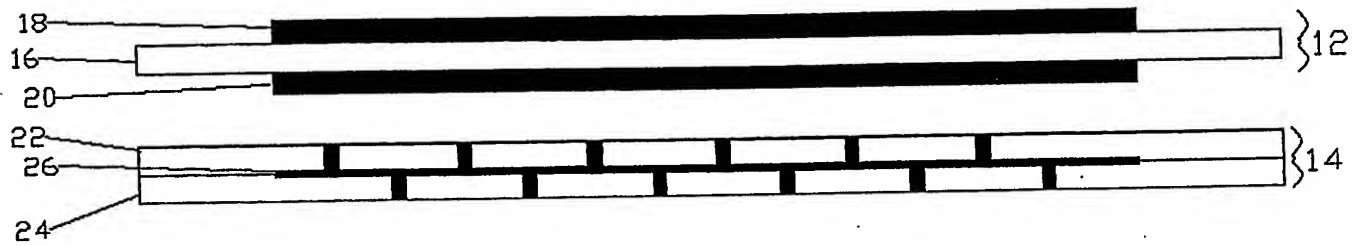
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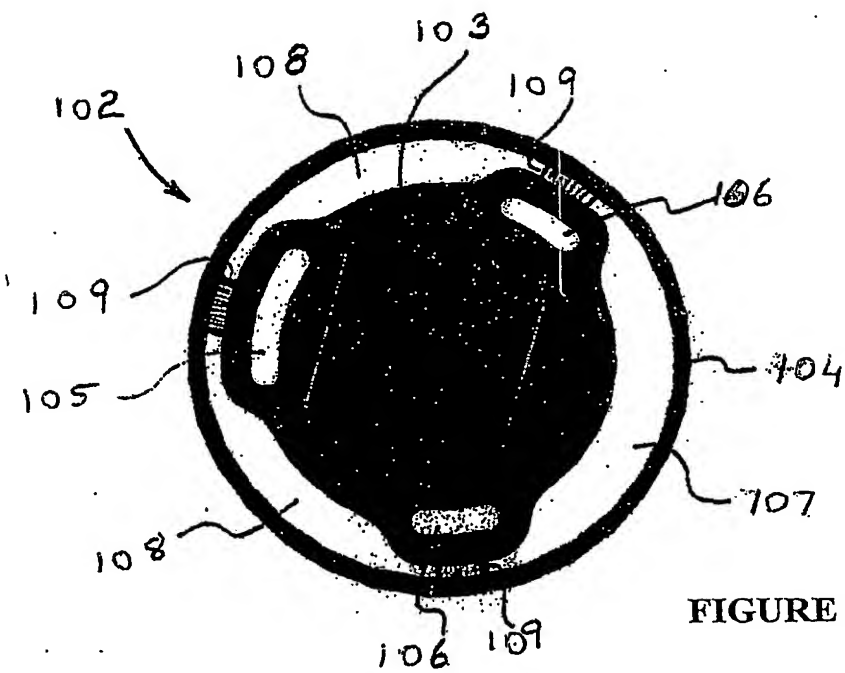
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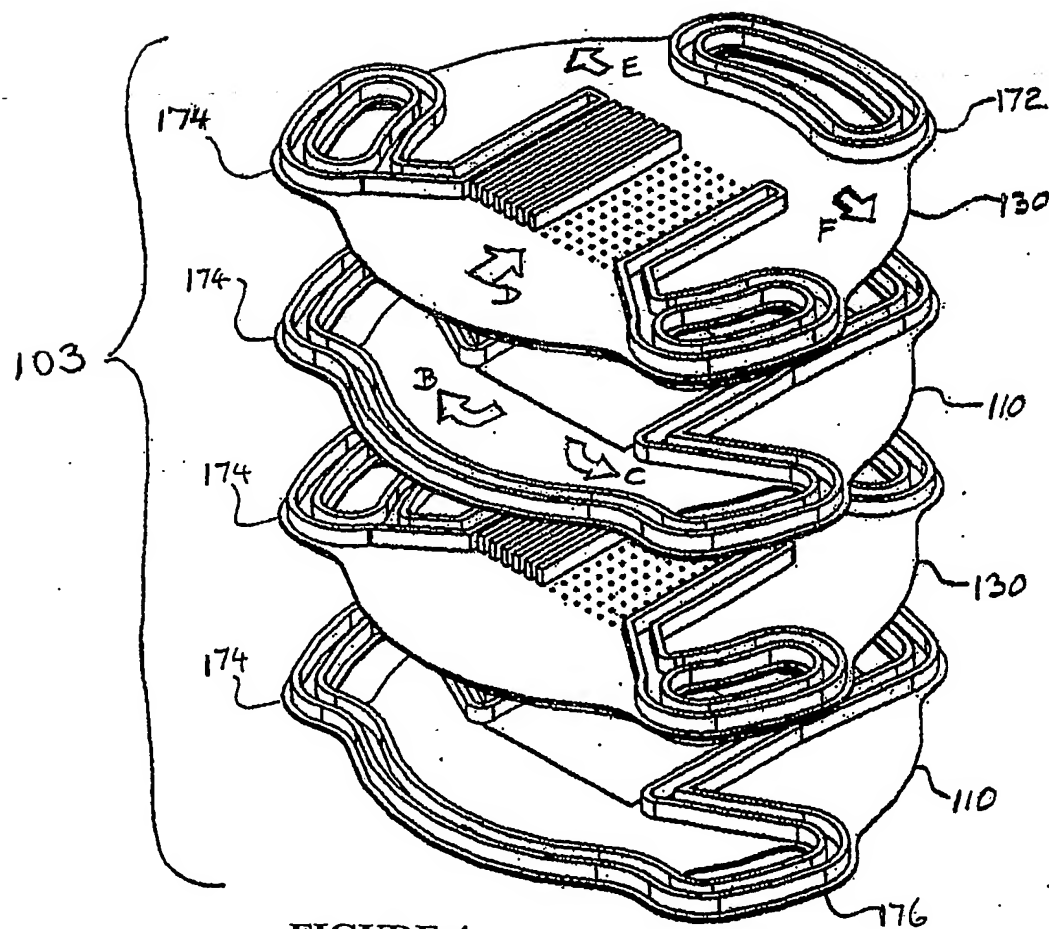
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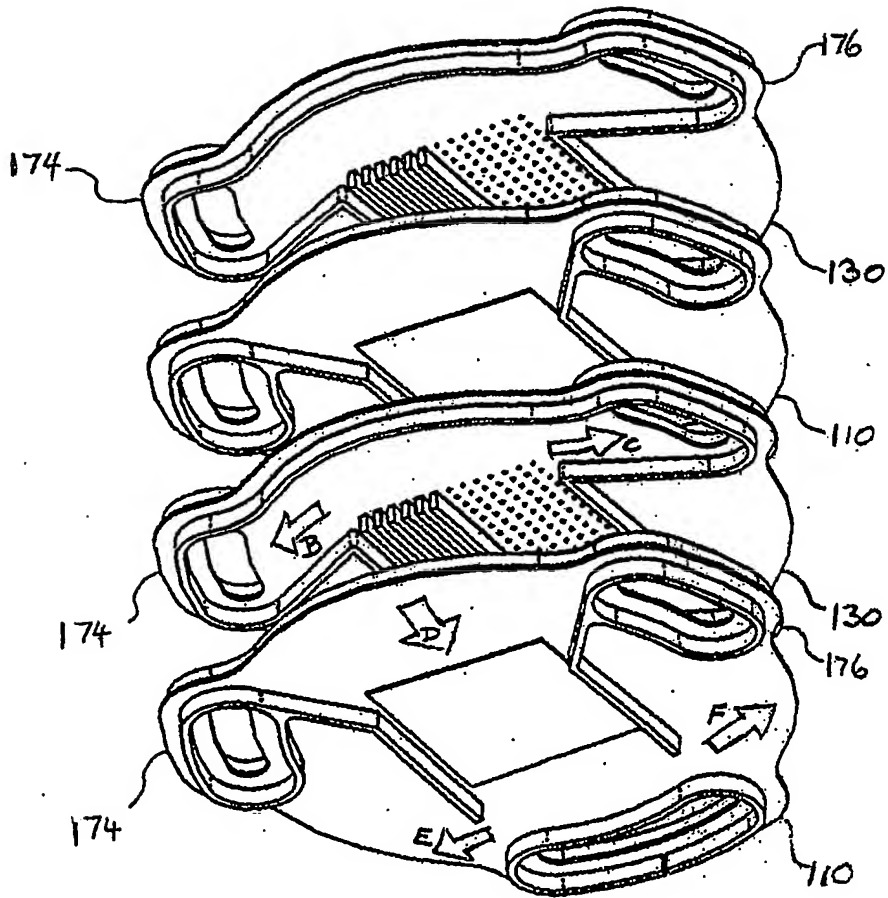
FIGURE 5

FIGURE 6

FIGURE 7

115

134

150   150   132

119

130

162 162

162

117

134

FIGURE 8

110

154   154

152

121   152   151

161   134

120

160

158   158

140

156

130
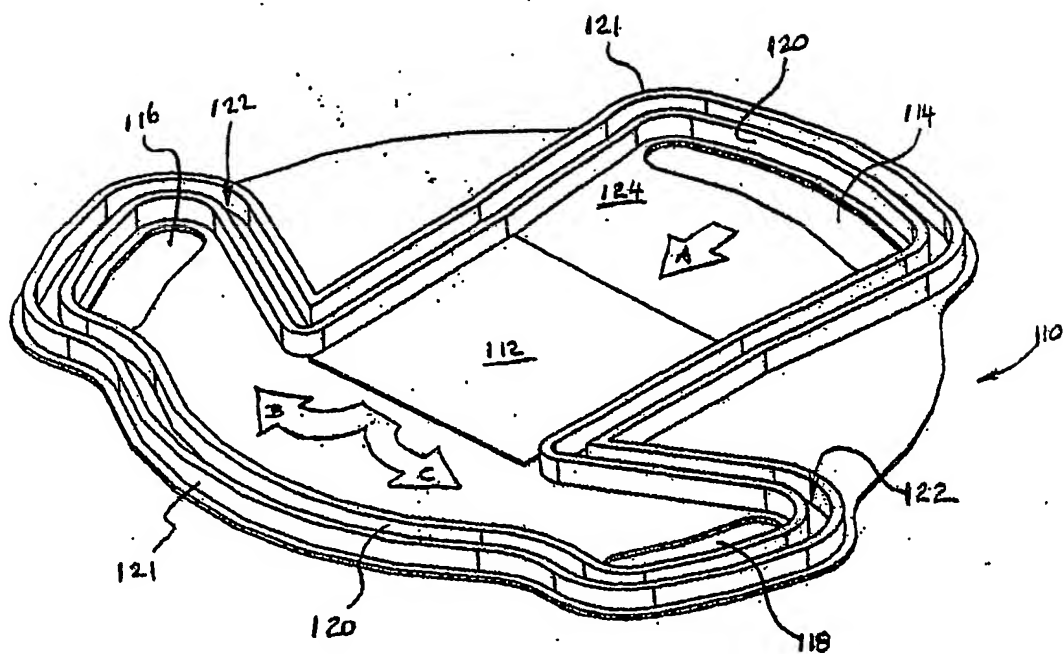
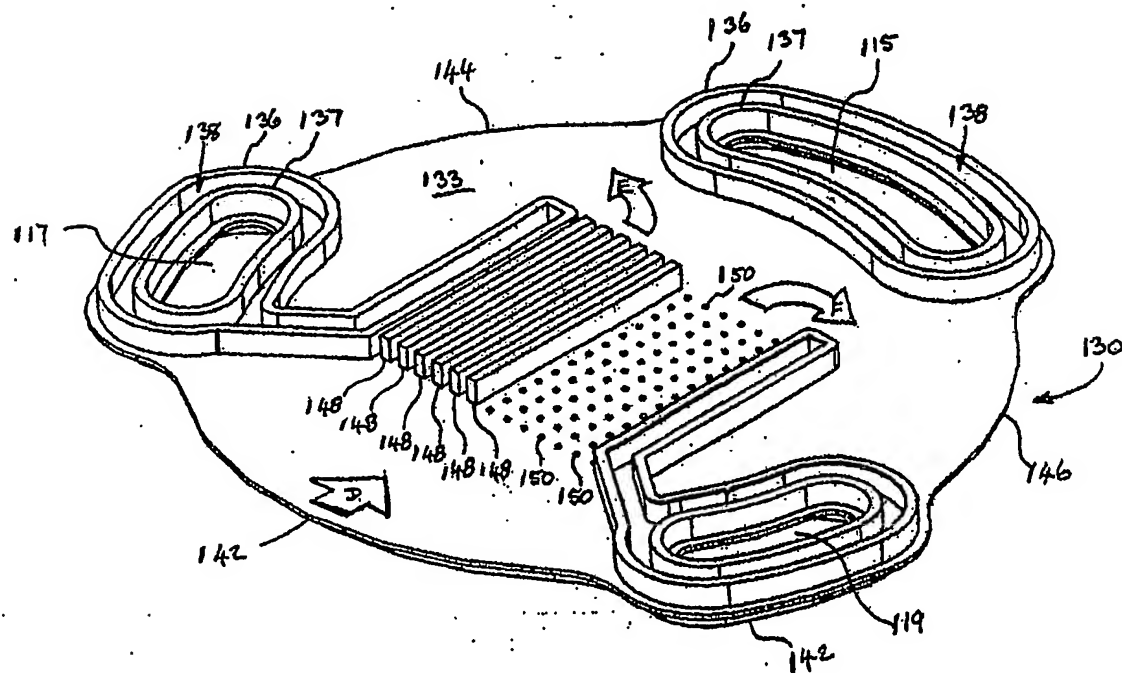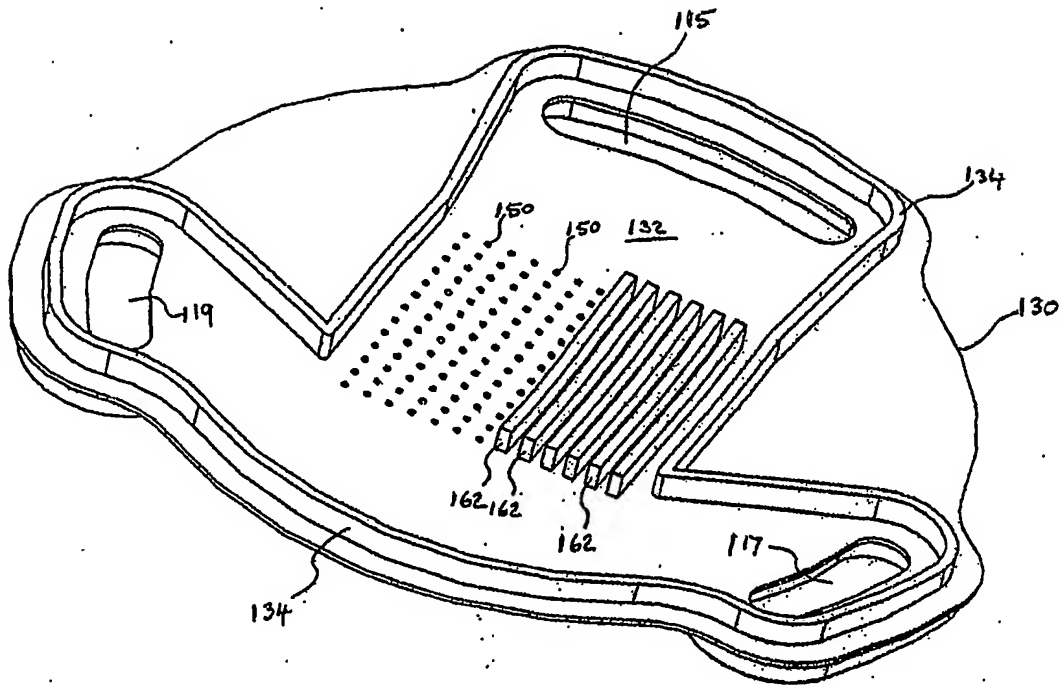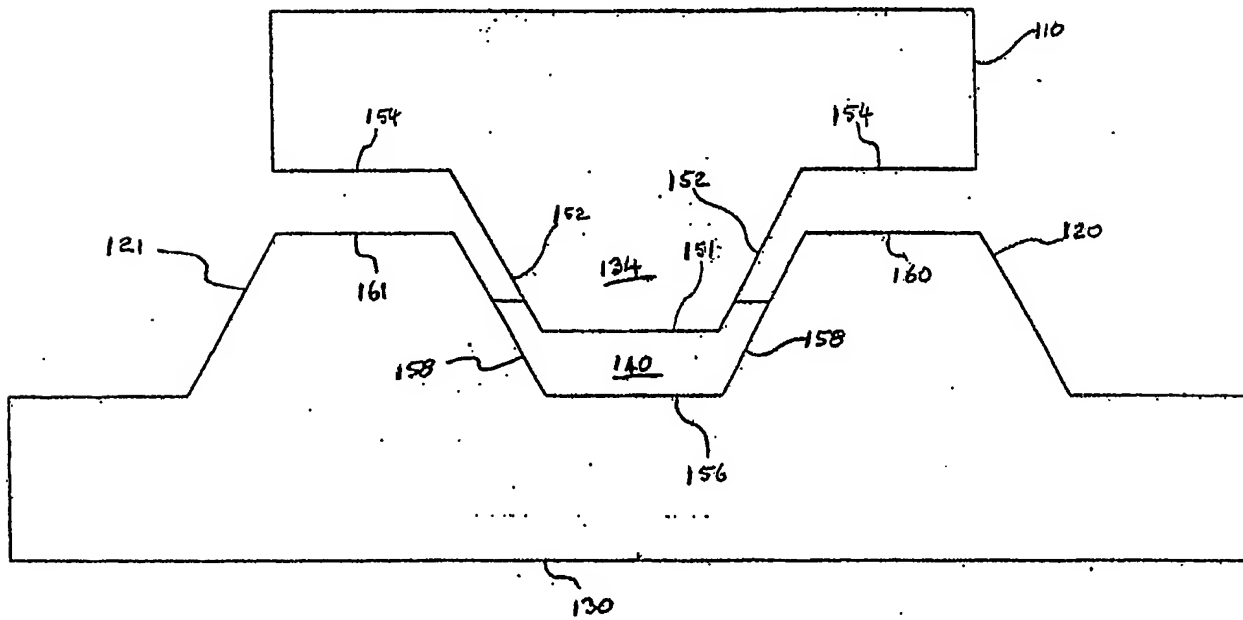**FIGURE 9**

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